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ABSTRACT

MATHS is a computer-assisted instruction (CAI) course in remedial mathematics for college level students. The course offers tutorial help in the areas of exponentiation, logarithms, and dimensional analysis, and drill in a number of basic mathematical skills. An attempt was made to allow the student to control his own course of study when using the program. To validate this approach, an experiment was conducted which separated students into five groups, each with different degrees of control over the course flow. An evaluation of course effectiveness and student attitudes was undertaken at the same time. It was concluded that the program is an effective instructional experience for the students who participated and that student attitudes concerning the program are generally favorable. In the area of student control, the results suggest that if students are to be given the option of deciding whether or not to enter a particular instructional segment, they should also be given control options within the instructional segment. If this is not the case, there is a tendency for students who need the instruction to avoid entering the instructional segment. Increased student control failed to improve student attitudes concerning the program. (JY)

THE UNIVERSITY OF TEXAS AT AUSTIN

Computer Assisted Instruction Laboratory

AUSTIN

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AN INVESTIGATION OF THE EFFECTS OF LEARNER CONTROL IN COMPUTER-ASSISTED INSTRUCTION PREREQUISITE MATHEMATICS (MATHS)

TECHNICAL REPORT NO. 5

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ORGANIZATION OF REPORT

A brief account of the development of MATHS, the justification of the program, the rationale of its design, and a list of areas of instruction are given in Sections 1 through 3. Program objectives and prerequisites are included in Appendix A. For a full documentation of the program, reference should be made to Smith and Gregory.[1] The Control Design, a unique feature of MATHS, is presented in Section 4. This section should be carefully studied before attempting to understand the levels of learner control embodied in the design of the evaluation. Section 5 outlines the specific hypotheses tested and the form of the more general evaluation. Section 6 contains an account of the methodology employed, including a narrative statement differentiating learner control levels.

Results of student trials are begun in Section 7. This section presents data bearing on the specific hypotheses and a secondary level of analysis to examine other relationships between beginning performance and post-course success.

Section 8 contains a brief examination of attitude questionnaire results, and Section 9 summarizes and discusses the obtained results.

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[1]Smith, Authella, & Gregory, Carl. *MATHS User's Manual*. Computer-Assisted Instruction Laboratory, The University of Texas, Austin, 1970.

SECTION 1: INTRODUCTION

At the university and college level, effective learning and instruction is often handicapped or even defeated by students' deficiencies in "prerequisite" mathematical skills. Because of these deficiencies, students in the physical sciences, engineering, mathematics, and other departments may fail because of "cumulative ignorance" in a subject matter which possesses dependencies upon these skills. Alternately, such deficiencies may require that instructors spend valuable class time providing review.

Coping with this problem adequately demands an individualized instructional system which will diagnose deficiencies for individual students and provide instructional materials prescribed on the basis of the diagnosis. The nature of this problem meets the following criteria for using the computer as both a diagnostic and instructional tool:

(1) The subject matter is well defined and can be described in operational terms.

(2) It can be analyzed into "modules" which can be employed flexibly to meet the prerequisites of a wide variety of college or university courses.

(3) The subject matter is not tied into lock-step semester or quarter based courses where scheduling problems become acute, but it is such that a student can take the CAI tests and lessons on his own time outside of the formal course structure.

(4) The information processing capabilities of the computer are well suited to the enormous task of providing an individualized test and selecting the best instructional materials for a given student.

(5) The tutorial and drill capabilities of the CAI system can be employed to optimize learning within any instructional module.

This modular diagnostic and testing system has a potentially wide applicability, hitting as it does the interface of college and high school. Conceivably, it could significantly improve learning and instruction in colleges and universities in a wide variety of subject areas dependent upon mathematical skills.

SECTION 2: PROGRAMMING DESIGN

MATHS is an extensive revision of an earlier development called PRESKILLS.[2] After considerable experience with the PRESKILLS course, the following modifications were made in the instructional design for MATHS:

A. An effort was made to remove the "mental block" many students indicated they had felt in learning from a machine. To do this, the role of the terminal as a *tool* for learning is emphasized. Past programs have placed requirements and demands on the student--a judgment on his ability to perform. MATHS is more textbook than instructor, more tool than controlling device. The steps taken to implement this objective were:

   1. Provide more learner control over what material to take, in what order, and in what quantity.

   2. Expand answer-processing techniques to allow less form restrictions for correct answers; expand wrong-answer evaluations to give more backup material for more types of wrong answers.

   3. When appropriate, to use messages indicating the nature of the course as a program written by a person, and, therefore, subject to human error.

   4. Make all display changes dependent on student action, i.e., no new messages until the student indicates that he is ready for a change.

B. To exploit modularity inherent in the design of MATHS, some basic course structures have been redesigned:

   1. Instruction sections now consist of "generalized" problems for which specific values are drawn from a table. For example, the question (3)(3) = ? is given. When the student answers correctly, he is returned to

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[2]Smith, Authella. *Design and programming of a computer-based diagnostic and tutorial course in college prerequisite mathematics.* Unpublished Master's Thesis, The University of Texas, Austin, 1969.

the beginning of the problem, but the problem has different values; e.g., (5)(5) = ?. The specific values for the problems are either stored in buffers as "tables" or are randomly generated. This type of problem design not only aids the objective of more learner control, but also can produce as many as 70 problems with only a relatively small increase in disk space over that previously required for one problem.

2. Every problem is now defined as a restart point (*prr*), to avoid redisplaying past material to a student either because he signs off between restart points and later returns or because of system failure in the middle of a student session.

3. Each display contains an identification label of the current problem in the upper left-hand corner.

SECTION 3: AREAS OF INSTRUCTION

The course offers tutorial areas (both instruction and diagnosis), drills, and a glossary. Tutorial and drill areas are as follows:

Tutorial

A. Exponentiation

1. Definitions of Exponents
2. Definition of Scientific Notation
3. Laws of Exponents and Their Application

B. Logarithms

1. Definition of Logarithms
2. Properties of Logarithms and Their Application
3. Common Logs from a Table of Mantissas
4. Antilogs from a Table of Mantissas

C. Dimensional Analysis

1. Unit Conversions
2. Solutions of Linear Equations

Drill

1. Whole number multiplication
2. Integer multiplication
3. Rational number (decimal) multiplication
4. Rational number (fraction) multiplication
5. Whole number addition
6. Whole number subtraction
7. Multiplicative inverse (reciprocal)
8. Integer addition
9. Integer subtraction
10. Rational number (decimal) addition
11. Rational number (fraction) addition
12. Rational number (decimal) subtraction
13. Rational number (fraction) subtraction
14. Whole number division
15. Integer division
16. Rational number (decimal) division
17. Rational number (fraction) division
18. Ordering numbers expressed in scientific notation
19. Scientific notation
20. Multiplication by power of 10 by decimal point shift
21. Nth root
22. Absolute value

SECTION 4: CONTROL DESIGN

In writing the MATHS course, an attempt was made to allow a student more control over his own course of study. To validate this course of action, students were separated into five groups, each having different degrees of control over their course flow. The control design was formulated for students having maximum control over the choice of material.

The student first encounters the Table of Contents which allows him to make increasingly specific selections of course material. For instance, the first choice for the student is between the areas of Exponentiation, Logarithms, Dimensional Analysis, and Drill Programs. If he selects Exponentiation, he then chooses between Definitions of Exponents, Definition of Scientific Notation, and Laws of Exponents. If he selects Definitions of Exponents, he must further indicate whether he wants to study Positive Integral Exponents, Zero Exponents, Negative Exponents, or Rational Number Exponents.

The student controls his progress in the program by means of control characters. The characters along with the resultant actions of each appear on the following page.

As will be discussed under Section 6, students were divided into five groups for experimental purposes, each having different degrees of learner control. The amount of control that a student had over his course of instruction depended on the control characters available to him.

These control options have been retained as a normal component of the program. A student is assigned a number (0-4), stored in counter 4, which determines the control characters he may utilize. The availability of control options for the different groups is given in Table 1, on the page immediately following the control characters.

Student Control Characters

Character	*Resultant Action*
e	Test items related to the current instruction are presented to the student enabling him to evaluate his progress.
b	The student is returned to the item that immediately precedes the current item.
s	The student is advanced to the item that immediately follows the current item. If the current item is the last in a frame (problem set), then he is transferred to the first item in the next set.
n	The student is advanced to the frame that immediately follows the current frame. (There may be several related items in a frame.)
t	The student is returned to the Table of Contents, resuming his place there. (The student's selection must be from the Table of Contents in order to begin under the learner control option. Under other options, he transfers to drills.)
c	The student is permitted to enter a free comment containing a maximum of 100 characters. The student resumes his work after entering his comment.
g	The student is permitted to look up a word(s) of his choice in a glossary. He resumes his work after using the glossary.
i	Instructional items related to the current test item are presented.
r	The student is returned to the problem *set* he was working with before referencing the glossary. (Under options 1-4, R returns the student from the drills to the problem set he was working on before entering the character T.)

TABLE 1

CONTROL OPTIONS DEFINING LEVELS OF LEARNER CONTROL

Experimental Groups					*Learner Control Options*	*Control Character*
4	3	2	1	0		
Program Control	Program/Learner Control			Learner Control	Instructional Sequence Options	
				A	Area Selection via Table of Contents	t
				A	Segment Selection via Table of Contents	t
				A	Section (Objective) Selection via Table of Contents	t
A	A	A	A	A	Selection of Drills via Table of Contents	t
					Options Available Within Evaluation and Diagnostic Tests	
	Access to Drills Only			A	Access Another Section via Table of Contents	t
		A	A	A	Skip This Test Question	n-s
		A	A	A	Jump Directly to Instruction for This Section	ı
A	A	A	A	A	Comment	c
A	A	A	A	A	Glossary Use	g
					Options Available Within Instructional Units	
	Access to Drills Only			A	Access Another Section via Table of Contents	t
	A		A	A	Skip to the Next Item in This Problem Set	s
	A		A	A	Jump to the Next Problem Set in This Section	n
	A		A	A	Jump Out of Instruction to the Evaluation Test for This Section	e
A	A	A	A	A	Comment	c
A	A	A	A	A	Glossary Use	g

Note.--"A" Indicates Availability of Learner Control Option

SECTION 5: OUTLINE OF SPECIFIC HYPOTHESES AND GENERAL EVALUATION

The MATHS program incorporated several types of learner control features. In an attempt to determine the effectiveness of the various types of learner control, the control program was rewritten so as to isolate the various control features. The specific hypotheses formulated concerning each type of learner-control feature are as follows:

1. It was hypothesized that when the decision of whether or not to enter a particular instructional sequence was left to the student, and he could use his performance on diagnostic test items as guidance if he wished, his posttest performance would be equivalent to that of a student for whom these decisions were made by the program on the basis of the same diagnostic tests. It was further hypothesized that the student under learner control would require less time to complete the material.

2. It was hypothesized that when the decision as to the amount of practice required within instructional exercises was left to the student, his posttest performance would be inferior to that of a student for whom the amount of instructional practice was determined on the basis of program evaluation of his performance in the instructional exercises. It was further hypothesized that the learner-control student would require less time to complete the material.

3. It was hypothesized that when decisions as to which instructional objectives were to be studied and their order were left to the student, his posttest performance would be equivalent to those students for whom the selection and sequencing of objectives were predetermined. It was further hypothesized that the learner-control student would require more time to complete the material.

As a supplementary topic of interest, student performances on typewriter and CRT terminals were compared. The chief difference for the student between the two terminals was in more rapid display by means of the CRT and the availability of hard copy for the typewriter terminal. There was also a suspected asthetic advantage to the CRT.

4. It was hypothesized that when instruction was provided by a terminal consisting of typewriter and image projector, the student's posttest performance would not differ from that of a student for whom instruction was provided by a terminal consisting of CRT and image projector. It was further hypothesized that the student using a typewriter terminal would require more time to complete the material than a student using a CRT terminal.

Since it was to be expected that students would enter the program with widely varying degrees of preparedness, as measured by a pretest, and since posttest scores and the cumulative response-latency data could be expected to be highly correlated with pretest scores, it was considered desirable to examine effects of the various learner-control levels and terminal conditions by means of a covariance analysis. The specific technique employed was that described by Bottenberg and Ward[3] as an analysis of treatment effects obtained in the presence of concomitant variables utilizing multiple linear regression analysis. Briefly stated, the analysis determined whether the expected values for posttest scores and latency data, as determined by regression coefficients obtained from pretest scores, were different for students in the four learner-control conditions or in the CRT and typewriter groups. In each case, the first hypothesis tested (by means of expressing the appropriate restrictions as linear equations) was that the increment of change in the expected values of the posttest scores (or cumulative response-latency scores) would be the same for each unit of change in pretest scores for all groups being compared. In other words, the test asked whether the regression lines were parallel.

A second set of analyses then tested the signficance of the differences between the means of the various groups. If the first analysis found that the regression lines did not deviate significantly from the parallel (which was the case in all but one instance), the analysis of mean differences was effectively an analysis of covariance which controlled for differences in pretest scores. The results of these two sets of analyses are presented in Section 8. The specific hypotheses discussed above were tested by means of orthoginal comparisons[4] based on the data resulting from the covariance analyses of mean differences.

Student attitudes regarding various aspects of the MATHS program were evaluated by administering an attitude scale after the student had completed the task. The general hypothesis tested was: Attitudes would be a positive function of the degree of learner control available to the student.

Finally, specific aspects of student performance in the program, as opposed to the external measures discussed above, were investigated.

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[3]Bottenberg, R. A., & Ward, J. H. *Applied multiple linear regression.* Technical Report PRL TDR-63-6, Lackland Air Force Base: Personnel Research Laboratory, March, 1963.

[4]Edwards, A. L. *Experimental design in psychological research.* New York: Holt, Rinehart, & Winston, 1968, p. 135-139.

SECTION 6: METHOD

Subjects

Due to the difficulty of obtaining a sufficiently large number of *S*s from any single source, they were drawn from a number of different sources. The majority of *S*s were members of five freshman mathematics courses at The University of Texas at Austin during the spring and summer semesters of the 1969-70 academic year. These classes consisted of students who did not have the prerequisite mathematical skills for admission to the freshman calculus course. Since all *S*s participated in the MATHS program on a volunteer, extracurricular basis, the number from each class who completed the program (or any one of the three portions of the program) was relatively small. The remaining *S*s were five students from an introductory physics class at The University of Texas at Austin, and four high school seniors who expressed an interest in studying the materials preparatory to entering college in September, 1970. Of the total of approximately 150 *S*s who were given the initial pretest, 85 completed the Exponents area, 51 completed the Logarithms area, and 36 completed the Dimensional Analysis area.

Following the spring semester, it became obvious that the subject *n* would be insufficient. As a means of increasing the number of *S*s per treatment group, one of the learner-control treatments (Condition 3) was dropped from the design, and *S*s who had been in this condition during the spring semester were consequently excluded from the study. This resulted in a reduction of the total *n* of available *S*s to 76, 49, and 32, for the Exponents, Logarithms, and Dimensional Analysis areas, respectively.

Determination of Performance and Attitude Ratings

All *S*s were given a series of three paper-and-pencil pretests, one for each of the three major course areas, prior to beginning the program (see Appendix B). For *S*s from the mathematics classes, the tests were group administered in the classroom with a 150-minute time limit. For all other *S*s the tests were administered in the laboratory and the same time limit was applied. This time limit was found to be very generous, and very few *S*s required the full amount of time. The use of paper-and-pencil tests, as opposed to tests administered at the terminal, was necessary to control differences between the availability of previous answers on the CRT and typewriter terminals. It also served as a limited control of the *S*'s aversive experience at the terminal. Since the pretests would be more or less aversive to the students as a function of their ability, it was held that if *S*'s first experience with a CAI terminal consisted of a test, this could be a contamination factor in the attitudes expressed by the students concerning their CAI learning experience. In addition to establishing a measure of the student's entry level, the tests were employed later in the study to determine which areas the student needed to study. An arbitrary criterion of 85% correct was established as passing. If the student's score on any one of the three area tests exceeded this value, he was not assigned the corresponding area in the program. In general, less than 10% of the students met criterion in any area on the pretest.

Parallel forms of the pretests for each area were administered to students after they completed that area, usually within a day or two. All posttests were administered in the laboratory, and, again, time limits were in effect although students seldom, if ever, needed the full time available.

At the time of the student's last visit to the laboratory, he was asked to fill out an 11-item attitude questionnaire concerning his experiences with the MATHS program (see Appendix D). Since a number of students ceased to participate in the program before completion, only 58 attitude questionnaires were available for evaluation.

Response latencies were recorded for all students participating in the program, and cumulative response times were determined for each of the major divisions in the program, i.e., the total student response time for the Exponents area, the Logarithms area, etc. This measure was of value in determining most aspects of instructional time requirements, but it did not include the time required for displaying the instructional materials. Since it was expected that this would be a non-negligible factor in the comparison of the CRT and typewriter terminals, a second time measure was recorded: the total time *S* was signed on the system while participating in the program. Two variables contributed to inaccuracies in this measure: the fact that *S*s did not always sign off the system when they left the terminal, and the fact that it was impossible to directly determine how much terminal time was devoted to each of the three instructional areas. With respect to the latter problem, terminal time per area was calculated by determining the ratio of response time per area to total response time and then applying this ratio to total terminal time. Because of the inaccuracies in this measure, it was used only when necessary, i.e., in the comparison of the CRT and typewriter terminals.

Terminals and Course Scheduling

All instruction took place in the CAI Laboratory, with the course being controlled by the IBM 1500 system. Two types of terminals were employed: five terminals consisted of 1510 keyboard, CRT, and 1512 image projector; three terminals consisted of 1518 typewriter and 1512 image projector. Students were randomly assigned to terminal-type at the time of the pretest administration and received all of their instruction from that terminal. Because there was not an equal number of each type of terminal available, approximately two-thirds of the students were assigned to CRT terminals and one-third to typewriter terminals. Student use of the terminals was on an *ad lib* basis, subject to the restraints of availability of terminals and other laboratory operations. In general, the students chose to work in blocks of one to two hours.

Definition of Experimental Conditions

The evaluation design may be viewed as a 2 by 4 factorial with two levels of terminal classes and four levels of learner control. The resulting eight groups were designated as C0, T0, C1, T1, C2, T2, C4, and T4, with the letters C and T representing CRT or typewriter terminals, and the numbers 0 through 4 representing decreasing levels of learner control. As mentioned previously, Groups C3 and T3 from the original design were deleted to conserve *S*s. Students from each subject source were randomly assigned to each of the eight groups. Due to the diminishing number of students who completed successive instructional areas, each of the three areas was evaluated separately. That is, the complete study can be viewed as consisting of three replications of the same experiment over the three instructional areas.

An evaluation of the relative merits of the CRT and typewriter terminals was made by a comparison of levels C and T. The potential interactions between terminal class and level of learner control was not examined due to the limited number of *S*s in each group.

Definition of the four levels of learner control is substantially more complex. To facilitate exposition, Group 0 can be labeled as the learner-control group, having the full complement of learner-control options available in the MATHS program, with the exception of the Drill Routines.* Groups 1 and 2 represent program/learner-control conditions in which some learner-control options were available to the student, but others had been replaced by program controls. Group 4 was run under full program control.

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*A number of programming errors were discovered in the Drill Routines during the first day of the experiment. Since a considerable amount of time was required to correct the errors, the Drill Routines were not made available to any students during the study, rather than having them be available to only those students who began at a later date.

Description of the various learner-control conditions would appear to be facilitated by beginning with the more structured, program-control groups, and then discussing the various learner-control options added to each group as they move toward full learner control. All of the program-control and learner-control groups, 1, 2, and 4, were similar in that the order of the instructional sequence was predetermined by analysis of the instructional objectives and was judged to be the optimal order of presentation of the greatest fraction of the student population. It was thus assured that all students in Groups 1, 2, and 4, were at least introduced to all concepts within the areas which they completed, i.e., for which they took a posttest. They were exposed to all of the instructional objectives in each course area, and they encountered these objectives in the same predetermined order. Two learner-control options were available to all students in Groups 1, 2, and 4 (as well as to Group 0): Students could request the use of the glossary at any time, and they could enter a comment at any time.

Each instructional area, Exponents, Logarithms, or Dimensional Analysis, consisted of several sections, each pertaining to a particular instructional objective. Within each section, Group 4 students were first given a short diagnostic test. If the student answered more than approximately 25% of the items incorrectly, he was branched to the instructional sequence pertaining to that objective. Otherwise, he was routed directly to the diagnostic test for the next section. Instructional sections were divided into problems, each problem relating to a particular aspect of the objective and consisting of one or more questions. The numerical values for each problem were generated algorithmically or by a table look-up procedure. Therefore, a particular problem could be repeated an indefinite number of times with varying numerical values. A student in Group 4 repeated each problem until he made two successful passes through the problem, answering all questions correctly on each pass. At that time, he proceeded to the next problem. Following the completion of all problems in an instructional section, the student was administered the diagnostic test for the next section, etc.

Group 2 students were given learner-control options in the diagnostic tests only. As they entered each section, they were directed to the first item in the diagnostic test for that section. In contrast to Group 4, however, a Group 2 student could skip individual test items by entering the control character *n* or jump directly from any part of the test to the beginning to that section's instructional sequence by means of the control character *i*. If the student completed the diagnostic test, he was *advised* as to whether or not he should take the instruction for that section on the basis of his test score. If, in the process of taking the test, he exercised the *n* option, those items which he skipped were counted wrong. If, after completing the test, the student chose not to take the instruction, he could jump directly to the diagnostic test for the next section via the control character *p*. If, on the other hand, he chose to enter the instructional sequence, he was locked into the same predetermined program control sequence employed for Group 4. That is, to complete the sequence, he was required to answer all parts of each problem correctly twice. Following the completion of the instructional sequence, he was routed to the diagnostic test for the next section.

As a student in Group 1 entered each section, he was routed to the first item in the diagnostic test, at which point he could complete the test, skip over individual test items, or jump directly to the beginning of the instructional sequence, exactly the same as a student in Group 2. He was also given advice as to whether or not he should take the instruction in that section and could skip over the instruction if he chose. Students in Group 1 differed from the Group 2 students in that if they did choose to enter the instructional sequence, learner-control options were available to them. Within the instructional sequence, the student could skip over individual questions within problems via the control character *s*, jump ahead to the next problem via *n*, or return to the previous problem via *b*. Effectively, the student could skip through the complete instructional sequence by means of repeated use of *n*. Whereas a student under program control was required to answer correctly all parts of a problem twice before going on to the next problem, a student under learner control repeated a particular problem as many times as he pleased and then moved ahead by means of *n* (or, of course, back to the previous problem by means of *b*).

Group 0 had the full complement of learner-control options available in the MATHS program. This group differed from Group 1 in that a student in Group 0 was able to determine his own overall sequence of instruction. That is, he could determine which instructional objectives he studied and the order in which he studied them. He could ignore some objectives and repeat the instruction for others. Group 0 students controlled their progress through the program via the additional control character *t*, which allowed the student to access the complete Table of Contents. From this table, he could move to any section of the program by entering the number of the area and the number of the section. Students in Group 0 differed from those in Group 1 in two other ways. First, Group 0 students were shown the objectives and prerequisites of each section as they entered the section and were advised that if they did not have the prerequisites, they might wish to go to an earlier section of the program to study these prerequisite skills. Since students in Groups 1, 2, and 4, could not alter their order of instruction, they were not shown these lists of prerequisite behaviors. Secondly, Group 0 students could jump out of the instructional portion of a section to an evaluation test (a parallel form of the diagnostic test) by means of the control character *e*. It might be argued that this option should also have been available to Group 1, but a Group 1 student who failed the post-instruction evaluation test would have had no direct access back to the instruction. He could have returned to the instruction by means of repeated use of the control character *b*, but it was considered unlikely that any student would have utilized this rather tedious method.

Evaluation Hypothesis 1, concerning the relative validity of author and student decisions about the student's need for instruction pertaining to a single objective was tested by means of a comparison between Groups 2 and 4. Hypothesis 2, pertaining to the relative validity of author and student decisions about the amount of instruction required to meet an instructional objective was tested by a comparison of Groups 1 and 2. Hypothesis 3, pertaining to the relative effectiveness of pre-selection and student selection of the number and sequence of objectives to be studied, was tested by a comparison of Groups 0 and 1.

A schematic representation of the various experimental groups, the learner-control options available to each group, and the functions of the learner-control options is provided in Table 1, Section 4.

SECTION 7: RESULTS

Evaluation of Specific Hypotheses

Due to the differing number of *S*s who completed each of the three major course areas, it was concluded that the most efficient way of utilizing the data would be to treat each of the three areas separately, each being, in effect, a separate replication of the experiment. Since more students completed the Exponents area (n = 76) than completed the Logarithms (n = 49) and Dimensional Analysis (n = 32) areas, the reader should probably give more weight to the results obtained in the Exponents area. Data from the Logarithms and Dimensional Analysis areas might be viewed as being supplementary, either confirming or confusing the Exponents area results.

In general, there was no interaction between the experimental variables and the students' pretest scores. In fact, such an interaction occurred in only one instance. Therefore, the data may be viewed as resulting from an analysis of covariance with the dependent variables, posttest score, cumulative response latency, or terminal time controlled for pretest score.

Data pertaining to the first hypothesis, concerning the relative effectiveness of program control and learner control in determining whether or not the student received instruction, is given in Table 2, appearing on page 22. It will be recalled that it was hypothesized that when the decision as to whether or not the student should enter an instructional area was left to the student, his posttest performance would be equivalent to that of a student for whom this decision was made under program control. In the Exponents area, the learner control group was found to have a slightly, but significantly, lower score than the comparable program control group. The trend in this direction was continued in the Logarithms and Dimensional Analysis areas, but in neither case was the difference significant. The fact that this comparison was also found to have a significant interaction with pretest score in the Exponents area may shed some light on the difference between the two groups. As can be seen in Figure 3, in this section, posttest score increased more sharply as a function of pretest score for Group 2 than it did for Group 4. It was those students who had the lower pretest scores who did the most poorly under the learner-control condition. It will be recalled that this particular group, Group 2, made their own decisions as to whether or not they would begin a particular instructional section. However, if they did choose to enter the section, instruction was given under program control. It may be the case that poorer students in Group 2 found the relatively restrictive programmed instruction sequence to be aversive and simply chose to enter fewer of the instructional sequences as the program progressed. Although such an explanation seems plausible, it is not supported by the cumulative latency data given in the lower half of Table 2. It would be expected that if these students did indeed skip more of the instructional sequences, the time required for them to complete the program would also be shorter. This was found not to be the case.

It was hypothesized that students under learner control (Group 2) would require less time to complete the program than would students under program control (Group 4). As is shown in the lower half of Table 2, this was not found to be the case. The only major difference in response times between the two groups occurred in the Logarithms area, and although the difference was in the anticipated direction, it was not significant. It must be concluded that students in the learner-control group did not require less time to complete the program.

Data pertaining to the second set of hypotheses, concerning the relative effectiveness of program control and learner control in determining how much practice a student should receive in a particular section, are given in Table 3 on page 23.

It was hypothesized that the posttest performance of the learner-control students (Group 1) would be inferior to that of the program control students (Group 2). As is shown in the first half of Table 3, the results from the Exponents and Logarithms areas were just the opposite of what had been anticipated--the learner-control students obtained higher posttest scores. Since the experimental hypothesis obviously had to be rejected, the significance levels cited are given in terms of a two-tailed test. With this test, only the difference obtained in the Logarithms area approached significance ($p < .10$). These results are gratifying, if unexpected, in that they suggest that the student was indeed at least as good a judge of when to terminate instructional practice as was the programmed decision rule.

Data pertaining to the second part of this hypothesis, that the learner control students would require less time to complete the material, are given in the lower half of Table 3. The results are inconsistent from one area to another, the learner control students being faster in the Exponents area and slower in the Logarithms and Dimensional analysis areas. In no instance did any of the differences approach significance. It must be concluded that there were no systematic differences in the amount of time required by students in the two different groups.

Data pertaining to the third set of hypotheses, concerning the relative effectiveness of program control and learner control in determining which instructional objectives were to be studied and the order in which they were to be studied are given in Table 4 on page 24.

It was hypothesized that the posttest performance of the learner control students (Group 0) would be equivalent to that of the program control students (Group 1). Again, the results were somewhat conflicting among the three areas. Posttest scores for the learner-control group were slightly inferior to those of the program-control group in the Exponents and Logarithms areas but were slightly superior to the program-control group scores in the Dimensional Analysis area. Only the Logarithms area data were significant.

It was further hypothesized that the learner-control student would require more time to complete the material than would the student under program control. This expectation was predicted on the assumption that the learner-control students would at least look at each of the instructional topics and that the order in which they investigated these topics would be less efficient than the order specified by the instructional designer. This assumption neglected the possibility that some students in Group 0 would simply ignore some topics altogether, as was found to be the case, particularly in the Logarithms area. The hypothesis tended to be supported in the Exponents and Dimensional Analysis areas, but neither difference was significant. Within Logarithms, the program-control students spent almost twice as much time as did the learner-control students, but the difference failed to approach significance due to the high variability in the data. It is interesting to note that the learner-control students had a significantly lower posttest mean score as compared to the program-control students. It would appear that the learner-control students simply skipped many topics in the Logarithms area altogether. The Group 1 (program-control) students had the option of jumping out of any topic without studying it, but the posttest and response-latency data, taken together, suggest that once these students were forceably introduced to the topics, they tended to study them. Although the data are far from conclusive, they do suggest that, under some conditions, it may be advisable to at least introduce the student to each of the topics in the material.

Data pertaining to the fourth hypothesis, comparing the performance of students run on the two different types of terminals, are given in Table 5 on page 25.

It was hypothesized that posttest performance would be equivalent for the students run on the two types of terminals, and this was, indeed, found to be the case. There was a slight, but consistent, tendency in favor of results of the typewriter-terminal students, but it never approached significance. The regression of posttest score on pretest score for the CRT and typewriter-terminal students is illustrated for all three instructional areas in Figure 1, which appears on page 26. It should be mentioned that the relative positions of the regression lines for the different program areas are somewhat misleading since there were different numbers of test items in each of the areas. Dimensional Analysis, for example, appears to be quite low in comparison to Exponents, but this is at least partly due to the fact that the Exponents test contained 30 test items, as contrasted with 13 items in the Dimensional Analysis test. As is shown in Figure 1 (and as is noted in Table 5), the regression of posttest on pretest was essentially parallel for the two terminal types in all three areas. That is, neither terminal type was particularly beneficial or deleterious for students of either high or low mathematical performance as measured by the pretest.

It was further hypothesized that students using the typewriter terminal would require more time at the terminal (as opposed to cumulative response time) to complete the program than would students using the CRT terminal. Data pertaining to this hypothesis are given in the lower half of Table 5. There was only a slight and non-significant difference in favor of the CRT terminal in the Exponents data, but substantial and significant differences in favor of the CRT terminals were found in both the Logarithms and Dimensional Analysis data. It is interesting to note that a strong practice effect seems to be indicated. All students in Groups 1, 2, and 4, and most students in Group 0, studied the materials in the order of Exponents, Logarithms, and Dimensional Analysis. While it is true that not all of the students studied all areas, in general, work in Dimensional Analysis was done following more experience with the system than work in Logarithms which, in turn, was done following more experience than work done in Exponents. Contrasting the two terminal types in each area, it is found that, on the average, students working with the CRT terminal spent 97.3% as much time as the typewriter students in the Exponents area, 72.8% as much time in the Logarithms area, and 62.7% as much time in the Dimensional Analysis area.

Since it seems more reasonable to attribute this increase to a practice effect rather than differences in the areas of student selection, it would appear that when students were first introduced to the system, they were unable to capitalize on the CRT's faster display attributes but became able to increase the efficiency of their interaction with the terminal as a function of practice. The finding that the difference was more pronounced in the Dimensional Analysis area than in the Logarithms area suggests that a substantial amount of experience with the terminal is necessary for the student to capitalize fully on the CRT's characteristics.

As an alternative to a practice effect, it might be hypothesized that since a smaller number of students completed the Logarithms and Dimensional Analysis areas than completed the Exponents area, the increasing difference between times of CRT and typewriter students could be due to some interactive selection process. To test this hypothesis, terminal times of the 18 students completing all areas were examined. Of the 18, 12 were assigned to CRT and 6 to typewriter terminals. Although the small sample size renders the data unstable, the trend observed was the same as for the total sample. In Exponents, CRT students required 157% as much time (159 minutes) as the typewriter students (90 minutes). In Logarithms, the proportion was 71% (166 minutes for CRT and 233 minutes for typewriter). In Dimensional Analysis, the proportion was only 53% (95 minutes as opposed to 179 minutes).

TABLE 2

LEARNER CONTROL VS. PROGRAM CONTROL ON DIAGNOSTIC TESTS

(concerning the decision as to whether the student should take instruction)

Area	*n*	*Mean*	*t*	*df*	*Interaction with Pretest Score*
		Posttest Score Data			
Exponents					
Group 2[a]	19	21.53			
Group 4[b]	13	25.39	2.78*	71	Yes
Logarithms					
Group 2	11	16.09			
Group 4	7	16.43	<1.00	44	No
Dimensional Analysis					
Group 2	7	9.86			
Group 4	6	10.33	<1.00	27	No
		Cumulative Response Latency Data			
Exponents					
Group 2	19	151.07			
Group 4	13	145.18	<1.00	71	No
Logarithms					
Group 2	11	140.36			
Group 4	7	220.57	<1.00	44	No
Dimensional Analysis					
Group 2	7	55.30			
Group 4	6	59.17	<1.00	27	No

*$p < .01$ (2-tailed)

[a]Learner Control

[b]Program Control

TABLE 3

LEARNER CONTROL VS. PROGRAM CONTROL IN INSTRUCTION

(concerning the decision as to when to terminate instructional practice)

Area	*n*	*Mean*	*t*	*df*	*Interaction with Pretest Score*
		Posttest Score Data			
Exponents					
Group 1[a]	16	23.37			
Group 2[b]	19	21.53	-1.51	71	No
Logarithms					
Group 1	9	18.11			
Group 2	11	16.09	-1.92*	44	No
Dimensional Analysis					
Group 1	7	9.86			
Group 2	7	9.86	<1.00	27	No
		Cumulative Response Latency Data			
Exponents					
Group 1	16	110.56			
Group 2	19	151.07	1.09	71	No
Logarithms					
Group 1	9	216.81			
Group 2	11	140.36	<1.00	44	No
Dimensional Anlaysis					
Group 1	7	69.19			
Group 2	7	55.30	<1.00	27	No

*$p < .10$ (1-tailed)

[a]Learner Control

[b]Program Control

TABLE 4

LEARNER CONTROL VS. PROGRAM CONTROL IN SEQUENCE

(concerning decisions as to the number and order of instructional topics to be studied)

Area	*n*	*Mean*	*t*	*df*	*Interaction with Pretest Score*
		Posttest Score Data			
Exponents					
Group 0[a]	28	21.86			
Group 1[b]	16	23.37	1.34	71	No
Logarithms					
Group 0	22	15.86			
Group 1	9	18.11	2.45*	44	No
Dimensional Analysis					
Group 0	12	10.75			
Group 1	7	9.86	1.44	27	No
		Cumulative Response Latency Data			
Exponents					
Group 0	28	124.31			
Group 1	16	110.56	<1.00	71	No
Logarithms					
Group 0	22	116.43			
Group 1	9	216.81	1.23	44	No
Dimensional Analysis					
Group 0	12	86.38			
Group 1	7	69.19	<1.00	27	No

$p < .02$ (2-tailed)

[a]Learner Control

[b]Program Control

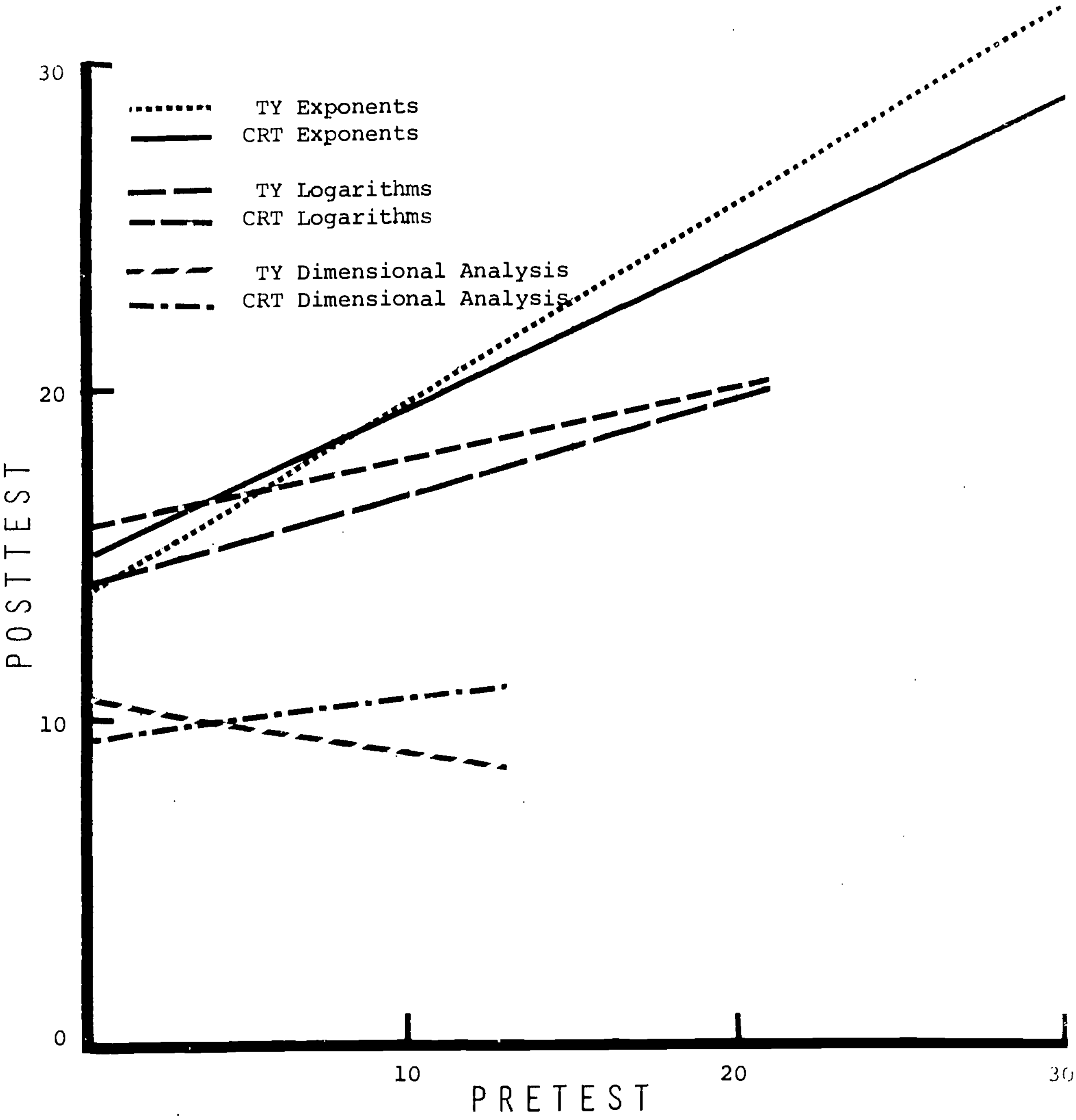

Figure 1.--*Regression Lines for Pretest and Posttest Scores for CRT and TY.*

TABLE 5

COMPARISON OF STUDENT DATA FROM CRT AND TYPEWRITER TERMINALS

Area		*n*	*Mean*	*t*	*df*	*Interaction with Pretest Score*
			Posttest Score Data			
Exponents						
	CRT	47	22.55			
	TY	29	22.93	1.67	1/73	No
Logarithms						
	CRT	34	16.06			
	TY	15	17.20	<1.00	1/46	No
Dimensional Analysis						
	CRT	19	10.16			
	TY	13	10.46	<1.00	1/29	No
			Total Terminal Time Data			
Exponents						
	CRT	47	206.80			
	TY	29	212.50	<1.00	1/73	No
Logarithms						
	CRT	34	232.40			
	TY	15	319.30	4.28*	1/46	No
Dimensional Analysis						
	CRT	19	103.70			
	TY	13	165.50	9.63*	1/29	No

*$p < .05$

Pretest/Posttest Gains for All Treatments

Analysis of results for all treatments combined showed gains from pretest to posttest with the Logarithm area of the program showing the greatest gain (8.5 difference between pretest and posttest means). The Exponents area was second in order of gain (6.3 difference in means), and the Dimensional Analysis area showed only slight gains (3.1 difference in means). Pretest, posttest, and latency means and standard deviations are presented in Table 6, below.

TABLE 6

MEANS AND STANDARD DEVIATIONS FOR PRETEST, POSTTEST, AND CUMULATIVE RESPONSE LATENCY

Program Area	*n*	*Mean*			*Standard Deviation*		
		Pretest	*Posttest*	*Latency*	*Pretest*	*Posttest*	*Latency*
Exponents	76	16.4	22.7	131.23	5.9	4.5	102.99
Logarithms	49	7.5	16.4	155.12	5.3	4.3	93.41
Dimensional Analysis	32	7.2	10.3	77.10	3.3	1.5	51.18

A regression line was calculated for pretest and posttest scores for all three program areas. The strongest relationship between entry-level and post-course skill was found to be in the area of Exponents (r = .60). Results for Logarithms showed a weaker relationship (r = .33), and there was no relationship between pretest and posttest scores for Dimensional Analysis (r = .06). As may be seen in Figure 2, on the following page, for every unit increase in pretest scores, the expected value of the posttest score increased .49 units for Exponents (standard error of estimate = 4.10). No appreciable increase in posttest scores for corresponding changes in pretest scores was observed in Dimensional Analysis. Some evidence concerning success in the program can be gained from Figure 2. The maximum possible scores for subtests were: 30 for Exponents (26 = criterion performance), 21 for Logarithms (18 = criterion performance), and 13 for Dimensional Analysis (11 = criterion performance).

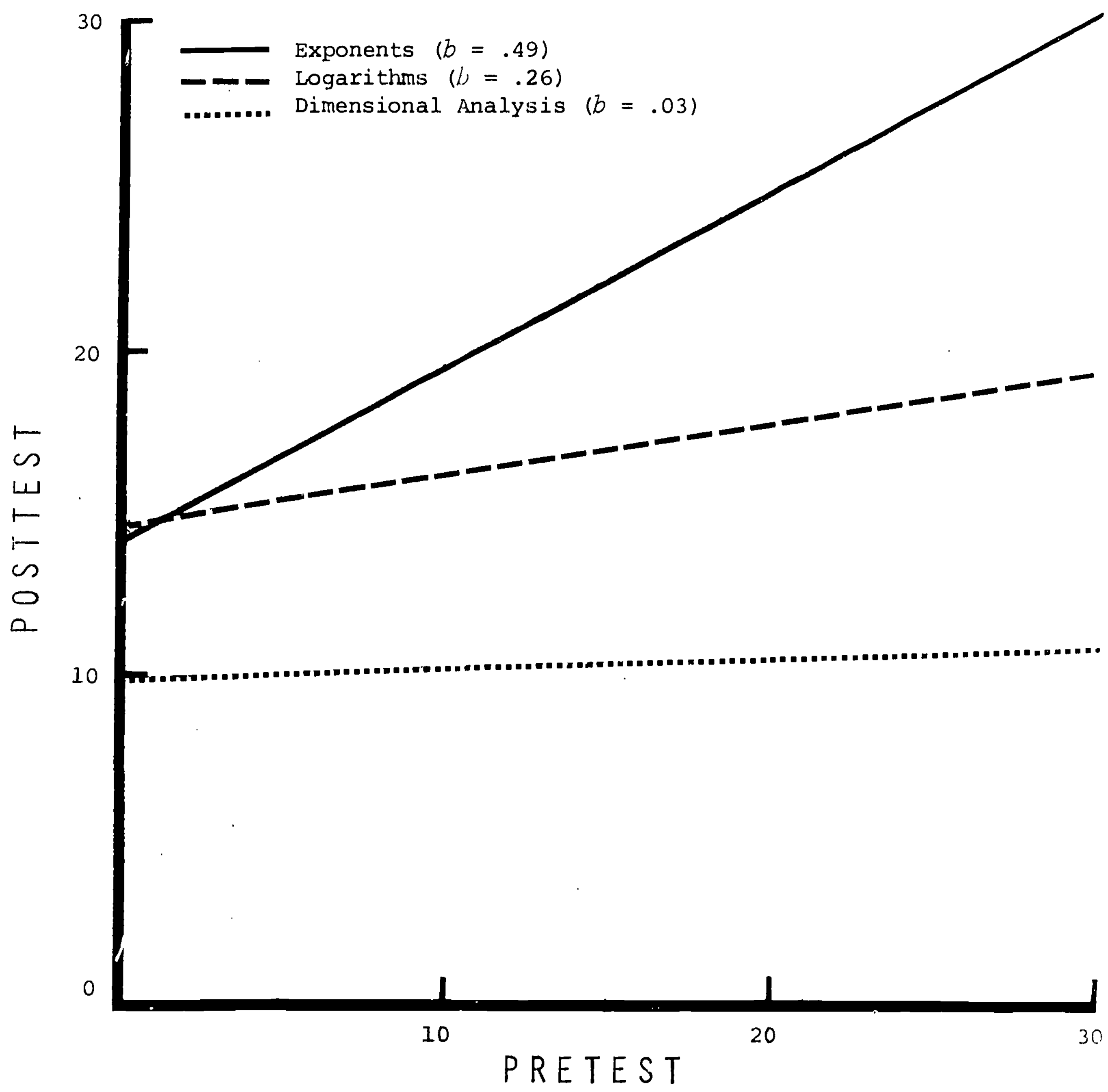

Figure 2.--*Regression of Pretest Scores on Posttest Scores for Three Areas of Program.*

The regression lines in Figure 2 show the trend of the relationship of entry-level to post-course performance, but they do not clearly indicate the magnitude of the learning in terms of how many students reached criterion performance (arbitrarily defined as 85% correct answers). The latter evidence is presented in Table 7, below. It might be noted that the area with the greatest success--Logarithms--was also the area in which the least amount of concurrent course learning was suspected.

TABLE 7

STUDENTS REACHING CRITERION PERFORMANCE

Areas	*n*	*Range of Pretest*	*Range of Posttest*	*Number Reaching Criterion on Pretest*	*Number Reaching Criterion on Posttest*	*% Reaching Criterion on Posttest*	*% Change from Pretest to Posttest*
Exponents	76	4-28	8-30	3	25	33%	29%
Logarithms	49	0-20	3-21	3	26	53%	47%
Dimensional Analysis	32	0-12	7-13	4	16	50%	37.6%

Results of Analysis of Learner Control Conditions as a Function of Pretest Score

Four levels of learner control were provided by program options ranging from full learner control (LC0) to full program control (LC4). A multiple linear regression equation was computed for the four learner-control conditions, and the resulting equation was tested against the assumption that the obtained values were sampled from the same population. The first hypothesis tested was that the regression lines were parallel (change in posttest scores for each increment of change in pretest scores were the same for all four levels). If lines were found to be parallel, then a second analyses was made to determine if the lines were concurrent (treatments equally effective over the observed range).

The regression lines for Exponents are plotted in Figure 3, appearing at the end of this section. The obtained probability that the four lines are not parallel approached significance (p = .135) with the greatest difference being in the lower pretest ranges for LC2 and LC4. Since a difference in LC2 and LC4 had been anticipated in a pre-stated hypothesis (Section 5), this particular difference was tested. In this instance, the deivation from parallel was significant (p = .02), as was noted in Table 2. The result is inconclusive, but as was noted previously, it does suggest that full program control was more effective for those students who were low in pretest scores in the area of Exponents.

The analysis of results in the area of Logarithms is displayed in Figure 4, at the end of this section. There is a tendency for LC4 to be more effective for those students high on pretest scores, but the obtained probability level (p = .33) does not permit this to be stated conclusively.

Results for the learner-control analysis for Dimensional Analysis are shown in Figure 5, also appearing at the end of this section. As may be seen in the plot of the regression lines, there was little difference in the four groups.

It must be concluded that learner-control conditions were the same for all four levels and for all levels of beginning proficiency.

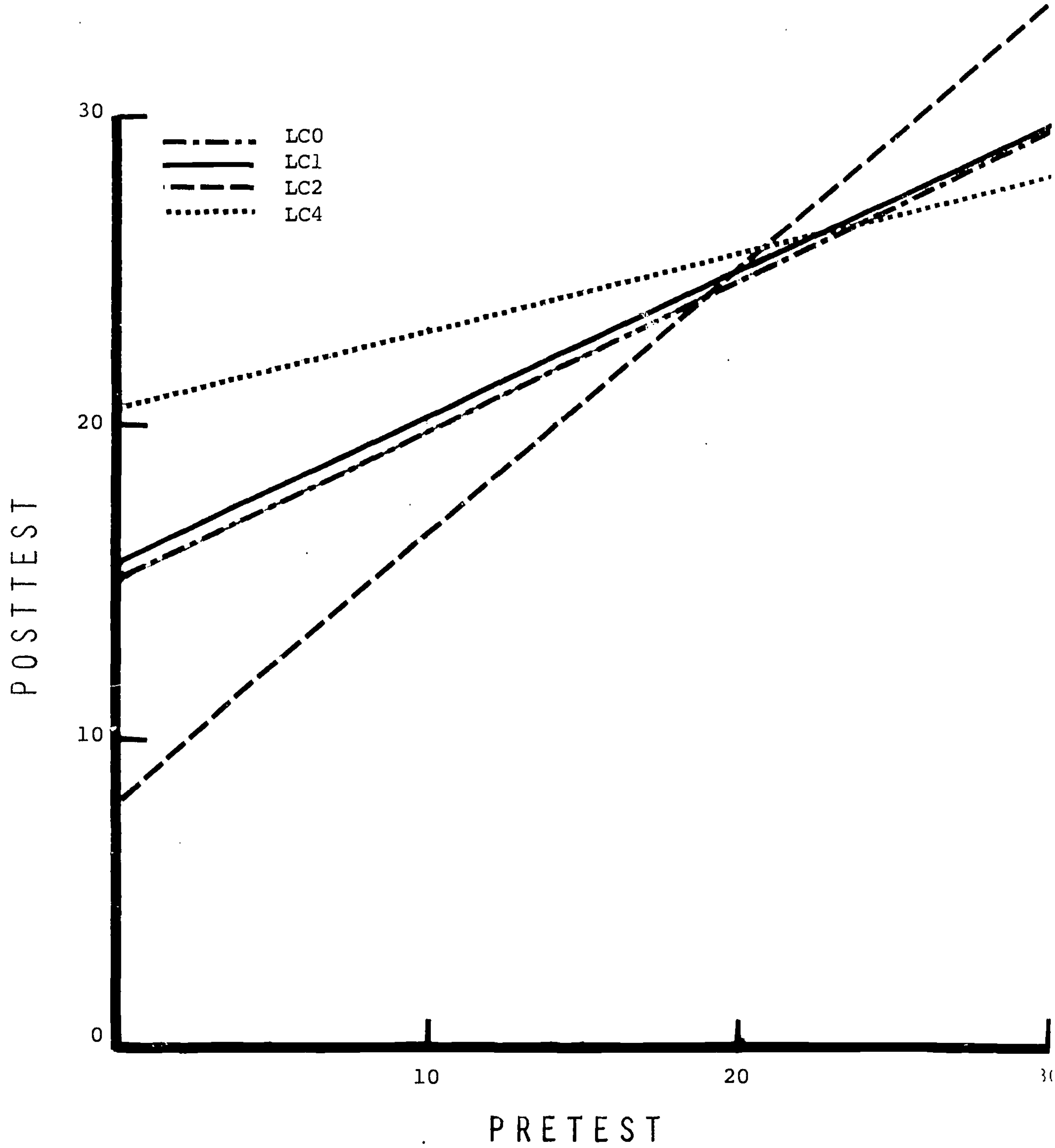

Figure 3.--*Regression Lines for Exponents: Pretest and Posttest Scores for Learner Control Conditions.*

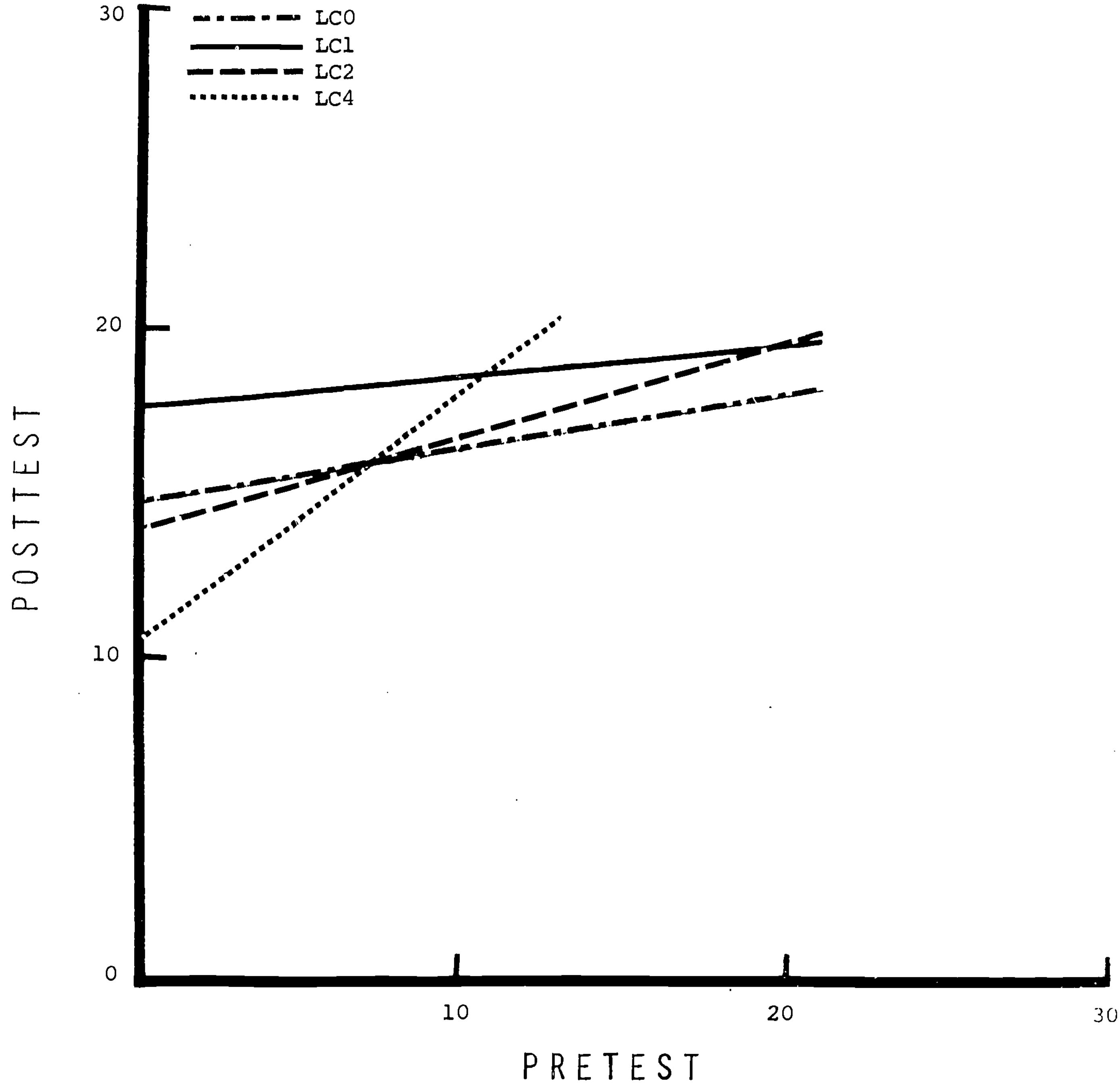

Figure 4.--*Regression Lines for Logarithms: Pretest and Posttest Scores for Four Learner Control Conditions.*

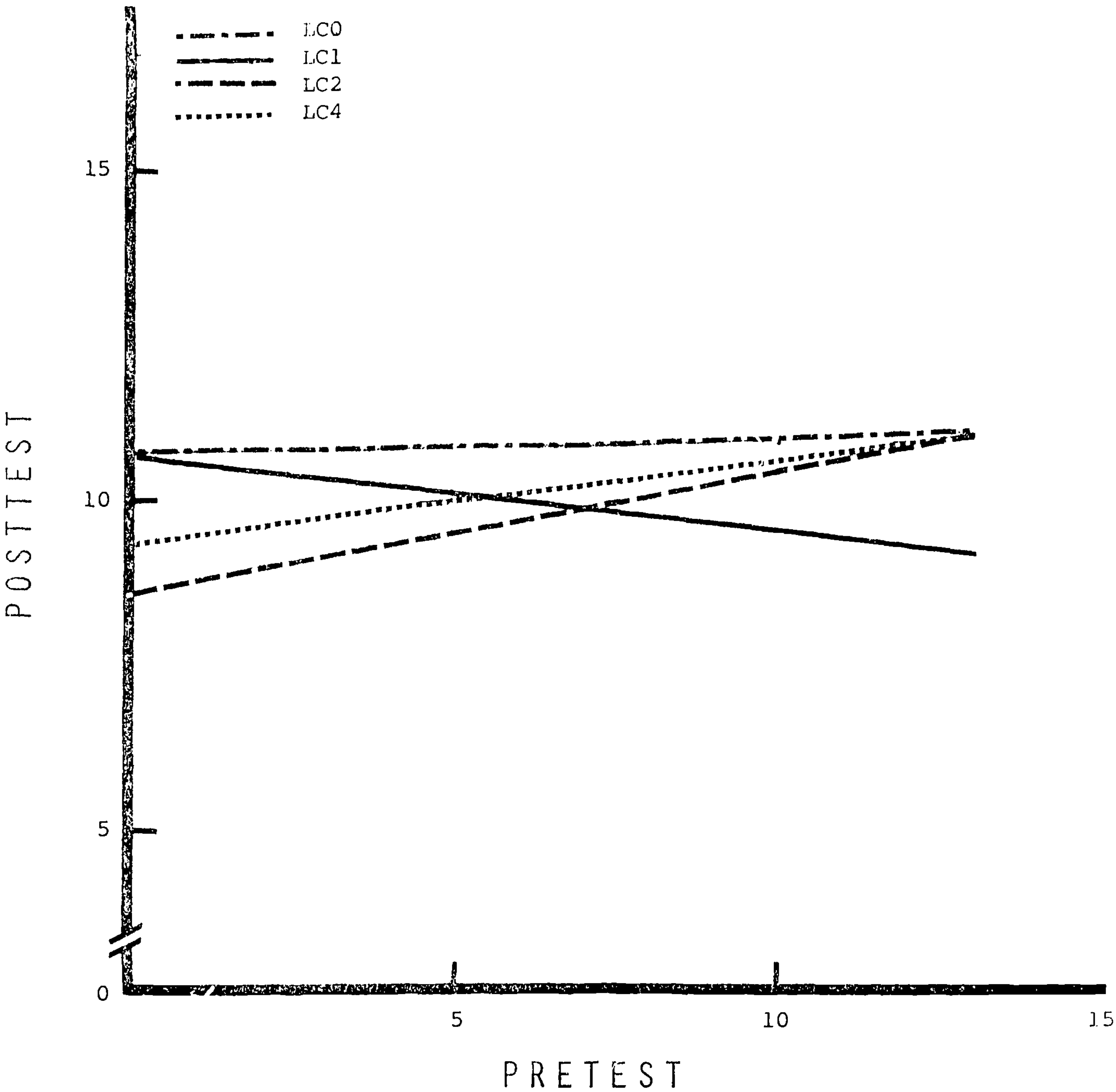

Figure 5.--*Regression Lines for Dimensional Analysis: Pretest and Posttest Scores for Four Learner Control Conditions.*

SECTION 8:

STUDENT ATTITUDE RESPONSES

An attitude inventory was administered to students as they began the program and again when they completed the program. No comparison between attitudes at the beginning and at the end was made, however, because of incomplete data. There were 58 complete responses on the post-administration. These responses were analyzed to determine overall reaction and to investigate possible differences between terminal types and between learner-control levels. The results for the first nine questions are reported below.

Question 1: "Do you feel that the CAI program helped you lose some of your hang-ups with regard to the equations and concepts used in your coursework?"

Response	*n*
It helped a great deal.	10
It helped some.	42
It didn't help.	4
It gave me more hang-ups.	2
	58

In general, students were positive toward the usefulness of the program in their other coursework. There were no significant differences for the type of terminal or the amount of learner control.

Question 2: "A CAI program comminucates with the student by means of either a typewriter keyboard or a TV-like screen. How do you like the terminal you used?"

Response	*CRT*	*TY*	*Total n*
I like it very much.	16	6	22
It is okay.	18	7	25
I really don't care for it.	2	4	6
I felt like a prisoner of a mechanical monster.	1	4	5
			58

Students working on the CRT terminal were more favorable to the machine than those working on the typewriter. A chi-square test of significance yielded a probability of less than .05 (X^2 = 8.051, df = 3) that the observed differences were not within chance expectancy. This was one of the few significant differences observed and was consistent with a suspected advantage for the CRT.

Question 3: "When the program presented concepts and rules for you to learn, were they clearly presented and understood?"

Response	*n*
In general, all the material was easily understood.	15
Most of the material was easily understood, but some was not.	35
Most of the material was difficult to understand.	8
In general, all the material was difficult to understand.	0
	58

The responses to Question 3 indicated that the content of the course was pitched at a level that was satisfactory to the students. No significant differences were noted between terminal types or control conditions.

Question 4: "Were the questions asked you by the program clearly stated so that you knew what kind of answer was expected?"

Response	*n*
They were almost always clearly stated.	6
Most were clearly stated.	35
Most were poorly stated.	16
They were almost always poorly stated.	1
	58

Although the majority of the students were satisfied with the way the questions were stated, a sizable number were not satisfied. Those not satisfied were about evenly distributed on terminal type, but those students who had some (but not full) restrictions on their control of the program were more dissatisfied than either those who had full program control or full learner control ($X^2 = 19.32$, $p < .05$). This may be seen in the following results:

	Learner Control			
	LC0	LC1	LC2	LC4
Satisfied (a + b)	15	7	10	9
Dissatisfied (c + d)	2	9	4	2
Total	17	16	14	11

Question 5: "CAI requires that you restrict your answers to one of a number of forms that the program can understand. Did you have difficulty in making the program accept your answers when they were really correct?"

Response	*n*
I seldom had any problems with the form in which I entered my questions.	3
I had some problems, but the program didn't seem to be too restrictive.	23
I had some problems and the program did seem to be too restrictive.	27
The program was so picky that it gave me a lot of trouble.	5
	58

Answer processing presented some problems for students. About half felt that the required answer forms were overly restrictive. Some of these responses may be from students who worked early in the trials when the program still had serious bugs.

Question 6: "It is always a problem to decide how quickly new material should be presented to the student . . . . Do you think this program moved too slowly or too quickly?"

Response	*CRT*	*TY*	*Total n*
Much too slowly.	2	3	5
A little too slowly.	12	12	24
Just about right.	22	6	28
A little too quickly.	1	0	1
Much too quickly.	0	0	0
			58

There was a tendency for students working at a typewriter terminal to be more negative about the pace of the program than those working on a CRT terminal. The difference was not conclusive, however ($X^2 = 8.42$; $p < .10$).

Question 7: ". . . As the student is given more control . . . [he] has to make more decisions about whether or not he really knows some topic and is ready to learn some other topic. Would you like to have more or less control over how the material is presented to you?"

Response	*n*
The program was much too rigid and I could have made better decisions on my own.	3
I would like to make a few more decisions on my own.	23
It seemed about right.	29
I had to make a few too many decisions.	2
I was so busy making decisions about what to do next that it slowed down my learning.	1
	58

There were no significant differences among learner-control groups in their responses to Question 7. About half of the students thought the available control was about right whether they had a lot or no control.

Question 8: "As compared to other ways of learning this material, I think CAI is:"

Response	*n*
Better than having an individual tutor.	8
About as good as having an individual tutor.	12
About as good as classroom instruction.	9
About as good as learning the material from a book.	27
Worse than learning the material from a book.	2
	58

There were no significant differences for students having different levels of learner control.

Question 9: "For the rest of the time you will be in college, how much of your instruction would you like to be by CAI?"

Response	*n*
I would like to take most of my courses by CAI.	4
I would like to take a few courses by CAI.	19
I wouldn't mind one or two courses by CAI.	29
I never want to use CAI again.	6
	58

In general, students were favorable to instruction by CAI. The responses to Question 9 are especially encouraging in view of the fact that many students early in the trials experienced considerable frustration with program bugs that delayed them or required a proctor's assistance, and in a few instances, caused them to repeat work already completed. No differences were noted for different terminal types or learner-control levels.

SECTION 9:

DISCUSSION AND CONCLUSIONS

In general, it may be concluded that the program was an effective instructional experience for the students who participated. While the pretest/posttest gains (Table 6) and the number of students reaching criterion on the posttest (Table 7) are not as great as might be hoped, substantial gains were demonstrated in all of the three instructional areas. The most dramatic improvement was in the Logarithms area, the one for which the students were least prepared (as indicated by their pretest scores). It is undoubtedly the case that the apparent effectiveness of the program was depressed to some extent by the limited gain scores of the students taking the course in the earlier stages of the experiment. At that time, the effectiveness of the program was severely diminished by the presence of methodological and programming errors. The performance of students taking the course during the later stages of the experiment showed a substantial improvement over that of the earlier students.

The attitudes expressed concerning the program, as measured by the attitude scale administered at the end of the program, were generally favorable. In view of the problems which the students experienced with the program during its earlier stages, the expressed attitudes could be interpreted as being quite favorable.

Any conclusions drawn about the relative effectiveness of the various learner-control options must necessarily be qualified due to the students' inexperience with relatively unstructured learning situations, the diminished number of *S*s who completed the more advanced program areas, and the difficulties with program errors during the earlier stages of the experiment. In spite of these limitations, however, several conclusions are at least suggested from the data.

First, it is suggested that if students are to be given the option of deciding whether or not to enter a particular instructional segment, basing their decision, in part, on the results of a diagnostic pretest, they should also be given control options within the instructional segment. If this is not the case (as it was not for Group 2), there is an apparent tendency for the students who do need the instruction to avoid entering the instructional segments. Posttest performance of the Group 2 students was not as high as that of both Group 4 students, who had no control options, and the Group 1 students, who had control options available during instruction. This was true for both the Exponents and the Logarithms areas. In Dimensional Analysis, Groups 1 and 2 had identical posttest scores, which were lower than the mean of the Group 4 scores.

Although the comparison cannot be made within the context of the current design, it is interesting to speculate as to whether a similar effect would be found if the selection of topics was controlled by the student (as was the case for Group 0), but control options were unavailable within instructional segments. It might be argued that students would not avoid the more difficult instructional sequences since they had elected to investigate the topics in the first place, but the results of the current study at least raise the question of whether or not this would be the case.

The data indicate that students who were given the option of terminating instruction (Group 1) performed at least as well as those who were required to reach criterion before exiting from an instructional sequence, but the comparison is weak in that the program-control group in this comparison was Group 2, for which it appeared that some of the poorer students chose to skip instructional segments which they should have studied. If Group 1 is compared to the full program-control group (Group 4), it is found that the students who were able to determine the amount of instructional practice fell only slightly below the program-control students in the Exponents and Dimensional Analysis areas and surpassed the program-control students in the Logarithms area. On the basis of these two admittedly-weak comparisons, the authors are inclined to suggest that students are indeed competent judges of the amount of practice which they require on given topics. While additional research pertaining to this question is obviously required, the results of the current study are most encouraging. If this aspect of the instructional process can justifiably be made the responsibility of the learner, it would eliminate many of the attributes of computer-assisted instruction which students seem to find objectionable.

Allowing the students to determine which instructional topics to investigate and the order in which these topics are taken appears to have had little beneficial effect as compared to the predetermined sequence. Students under full learner control (Group 0) demonstrated an average posttest score lower than that of Group 1 in both the Exponents and Logarithms areas and higher in the Dimensional Analysis area. The only significant difference was in the Logarithms area and it is noteworthy that, on the average, Group 0 students spent only about half the time working in this area as did the Group 1 students. Since Logarithms was the area with which the students were, in general, the least familiar, the data suggest that an author-defined sequence may well be more important for those areas of instruction in which the student is the least competent. If a student has had some success in dealing with a particular area in the past, as indicated by a higher pretest score, he may well be more likely to select topics for further study in that area than if he has had only very limited past success with the area. Knowing that if he selects a particular topic he will be forced to put forth a considerable effort to complete the topic, he may completely neglect the topic altogether. On the other hand, simply introducing the student to the topic, as was done in the case of Group 1, appears to greatly increase the probability that the student will persist in studying that topic. Thus, it is suggested that while student selection of topics may be effective for areas of study in which the student has demonstrated some competence (or perhaps, areas which are completely novel), a degree of program control which at least leads the student to the topic may be preferable in situations in which the student has relatively little competence or which he has found to be onerous in the past.

The anticipation that learner control would result in improved student attitudes concerning the program was definitely not substantiated. Only one item, concerning the clarity of the questions stated by the program, was found to interact with the various levels of learner control. As was discussed, this was a complex interaction in which those students who had intermediate levels of learner control tended to state that they found the questions poorly stated. There is no obvious explanation for this interaction. It might have been that the intermediate levels of learner control may themselves have tended to be confusing to the students, leading, in turn, to confusion about the specific questions. If this were the case, however, it would seem as though the effect would have been detected by some of the other attitude scale items.

The comparison of student performance on CRT and typewriter terminals substantiated the hypothesized advantage of CRT terminals. The average posttest scores of the typewriter students were consistently higher than those of the CRT students, but the differences were only slight and nonsignificant. This tendency is most easily explained in terms of the availability of previous examples for the typewriter terminal students. For some subject matter, the availability of such previous examples might be a more influential factor, but it is difficult to imagine a program in which this would be more the case than it was in MATHS.

On the other hand, comparison of the terminal types in terms of the amount of time required for students to complete each of the three areas demonstrated a substantial advantage in favor of the CRT terminals. It is interesting to note that this difference was not apparent until the students had spent more than three hours working with the terminals. Due to the novelty and speed of presentation of the CRT terminals, the results of any comparison made before students became accustomed to using the CRT display effectively would be quite misleading. Under conditions analogous to those present in the Dimensional Analysis area, the data indicate that three students using CRT terminals could complete a program in slightly less time than would be required for two students to complete the same program using typewriter terminals. While the reliability of this comparison is open to question, it is a factor which certainly should be taken into account in any considerations of cost effectiveness.

Two of the items on the attitude questionnaire also indicated a student preference for the CRT terminal. Responses to item 2, which addressed the question directly, indicated a significantly greater proportion of favorable responses from students who had used the CRT terminal. Student responses to item 6, concerning the rate at which the program was paced and designed to detect differences among the various levels of learner control, were particularly interesting. Although the actual rate of presentation was counterbalanced across terminal types, a greater proportion of students using typewriter terminals apparently perceived the program as being presented at too slow a rate.

APPENDIX A

OBJECTIVES OF MATHS

APPENDIX A

OBJECTIVES AND PREREQUISITES FOR ALL TUTORIAL AREAS

EXPONENTIATION

Segment I

Objectives: Express without exponents any number b^n where b is a non-zero real number and n is:

1. a positive integer (1, 2, 3, . . .)
2. zero
3. a negative integer (-1, -2, -3, . . .)
4. a rational number (1/2, 2/3, . . .)

Prerequisites:

1. whole number multiplication
2. integer multiplication
3. rational number multiplication
4. multiplicative inverse
5. square root, cube root, . . .

Segment II

Objectives:
1. Tell at a glance if an expression is scientific notation for some rational number x.
2. Write scientific notation for x, a rational number.

Prerequisites:

1. Exponential notation for integral powers of ten; e.g., 10^{-5}, 10^{0} , 10^{2} are integral powers of ten in exponential form.

2. Mental multiplication of integral powers of ten or rational numbers expressed in decimal form.

Segment III

Objectives: If a and b are real numbers, m and n are positive integers, rewrite expressions using:

1. $(b^m)(b^n) = b^{m+n}$
2. $b^m/b^n = b^{m-n}$, $b \neq 0$, $m > n$
3. $(b^m)^n = b^{mn}$
4. $(ab)^n = a^n b^n$
5. $(a/b)^n = a^n/b^n$, $b \neq 0$
6. any combination of the above

Prerequisites:

1. whole number addition
2. whole number subtraction
3. rational number multiplication
4. rational number division
5. positive integral exponents

LOGARITHMS

Segment I

Objectives:

1. Write the exponential form of an equation given the logarithmic form and vice-versa.
2. Use the definition of logarithm to solve, by inspection, equations of the form:

   $$\log_b(p) = x$$

   for b, p, or x if x is an integer or a fraction.

Prerequisites:

Definition of rational exponents.

Segment II

Objectives: Use the following properties of logarithms to rewrite expressions containing log forms:

1. $log_b(xy) = log_b(x) + log_b(y)$
2. $log_b(x/y) = log_b(x) - log_b(y)$
3. $log_b(m^n) = n\ log_b(m)$
4. any combination of the above

Prerequisites:

1. five laws of rational exponents
2. definition of logarithm

Segment III

Objectives:

1. Determine the common logs of integral powers of 10 by inspection (definition).
2. Find, in a table of mantissas, the common logs of numbers between 1 and 10.
3. Apply log property 1 and the above to obtain common logs of numbers greater than 10.
4. Find common logs (as in 3 above) of numbers between 0 and 1 and express as:

   a. $m + c$
   b. x (calculated sum of $m + c$)

Prerequisites:

1. Scientific notation
2. Addition of rational numbers (decimal notation)
2. Log property 1

Segment IV

Objectives: Reverse the procedure for finding common logs to obtain the antilog of:

1. A positive logarithm which is expressed as a positive number.

2. A negative logarithm which is written as:

   a. the indicated sum $(m + c)$ of positive mantissa and negative characteristic.

   b. a negative number.

Prerequisites: The procedure for using a table of common logs to find common logs of numbers.

DIMENSIONAL ANALYSIS

Segment I

Objectives: Express a given quantity in terms of a specified unit given the relationship among the units.

Prerequisites:

1. addition and multiplication of real numbers

2. eleven basic properties of arithmetic and algebra, e.g., commutativity

3. definition of positive integral exponents

Segment II

Objectives: Solutions of linear equations which have the forms:

1. $ax = b$
2. $ax + b = c$
3. $ax + b = cx + d$
3. $ax + b = cx + d$

   $a(x + c) = b(x + d)$

4. $ax + bu_1 = cx + du_2$

   (u_1 and u_2 are units of measure)

Prerequisites:

1. addition and multiplication of real numbers
2. eleven basic properties of arithmetic and algebra, e.g., commutativity

APPENDIX B

PRETEST AND POSTTEST

APPENDIX B:

PRETEST AND POSTTEST

EXPONENTS

Test A	1	2	3	4	5
1. $(-6/5)^3 =$	$(-6)^3/5^3$	none of these	$-6/5^3$	$6^{-3}/5^3$	$(-6)^3/5$
2. $0.4^{1/2} =$	$1/\sqrt[2]{0.4}$	1/0.16	0.2	-0.16	none of these
3. $(1.86)(10^0) =$	none of these	0	1.86	1	0.186
4. $(11)^7/11 =$	$11^{7/1}$	11^6	none of these	$11^{(1-7)}$	11^8
5. $[(6)(4)]^6 =$	none of these	$(24)^{12}$	$(6)^1(4)^6$	$(6)^6(4)^6$	$(6)^3(4)^3$
6. $[(8.10)(10^3)]/[(9.00)(10^{-5})] =$	$(-0.90)(10^2)$	$(9.00)(10^7)$	$(9.00)(10^{-7})$	$(9.00)(10^8)$	none of these
7. $[5(-z)(y)]^3 =$	$5^3(-z)^4\ y^4$	none of these	$125(y-z)^3$	$15\ z^3\ y^3$	$(-125zy)^3$
8. $x^4/y^2 =$ $(y \neq 0)$	$xy^{4/2}$	none of these	xy^6	x^4-y^2	xy^2
9. $(6^8)^{-3} =$	6^{-5}	none of these	6^5	6^{24}	6^{-11}
10. Express $(1.2)^2$ in scientific notation.	$(1.44)(10^0)$	$(1.44)(10^1)$	$\log_{10}(1.41) = 0.1492$	none of these	$\log_{1.2}(1.44) = 2$

Exponents - Page 2

Test A	1	2	3	4	5
11. $(3)^{12} =$	$(3^{-4})^{-3}$	$(3^6)^6$	$[(3)]^9$	$(3^{-4})^{16}$	none of these
12. $[(r-0.02)^v]^{4z} =$	$(r-0.02)^{v+4z}$	$(r-0.02)^{4z/v}$	none of these	$(r-0.02)^{4vz}$	$(r^v-0.02^v)^{4z}$
13. Express 793,000,000,000 in scientific notation.	$(79.3)(10^{10})$	$(7.93)(10^{11})$	$(793)(10^9)$	none of these	$(0.793)(10^{12})$
14. $(5^3)(5^9) =$	5^{27}	25^{27}	none of these	$5^{9/3}$	5^{12}
15. $(cd)^5x^{-8r}(cd\ x^r) =$	$(cd)^4x^{-9r}$	$(cd)^5x^{8r}$	$(cd)^5x^{-7r}$	$(cd)^4x^{9r}$	none of these
16. $(-0.24)^{-2} =$	none of these	$\sqrt[2]{-0.24}$	0.48	$(0.24)^2$	1/0.0576
17. $(-0.05)(10^3) =$	1/50	-0.0005	-50	none of these	0.00005
18. $(0.003)(3^{10}) =$	$(3.0)(3^7)$	$(3.0)(3^{13})$	0.0000000000003	30,000,000	none of these
19. $[(2x-3z)^3]^2 =$	$(3x)^6-(3z)^6$	none of these	$(2x)^5-(3z)^5$	$(2x-3z)^5$	$(2x-3z)^{(3)(2)}$
20. $4^{3/2} =$	0.125	8	none of these	$1/(4)^{2/3}$	$\sqrt[3]{16}$
21. $(9^{5/2})(9^{1/2}) =$	$9^{5/4}$	none of these	9^5	9^2	9^3
22. $[(2-3)(2+4)]^3 =$	$(2-3)^3(2+4)^3$	$(2-3)^4(2+4)^4$	none of these	$2^6(-3)^3 4^3$	6^3

Test A	1	2	3	4	5
23. $2^0 =$	0	1	2	1/2	none of these
24. $(8/-7)^5 =$	$8^5/(-7)^{-5}$	none of these	$8/(-7)^5$	$8/7^{-5}$	$8^5/7^{-5}$
25. $(x+2y)^3(x+2y)^{-4} =$	none of these	$(x+2y)^{-12}$	$(x+2y)^{-7}$	$(x)^{-1}+(2y)^{-1}$	$(x+2y)$
26. $(-4/3)^{-4} =$	$3^4(-4)^4$	$4^4/3^{-4}$	$(-4)^4/3^{-4}$	$3^4/(-4)^4$	none of these
27. $(-2)^{-1} =$	-1/2	none of these	0	2	-1
28. Express (-0.00047)(0.2) in scientific notation.	$(-940)(10^8)$	$(-9.40)(10^6)$	$(94.00)(10^7)$	none of these	$(-0.940)(10^5)$
29. $(5/3)^{-3} =$	$(-5)^3/(-3)^3$	$5^{-3}/3^{-3}$	$5^3 3^3/1$	$5^3/3^{-3}$	none of these
30. Express -0.04 in scientific notation.	$(4.0)(10^{-2})$	$(-0.2)^2$	none of these	$\log_{0.2}(-0.04) = 2$	$-(0.2)^2$

LOGARITHMS

Test A	1	2	3	4	5
31. $\log_b(c)-\log_b(d) = \log_b(x)$ $x =$	none of these	c-d	$b^{(c-d)}$	c/d	-cd
32. Solve for P. $\log_8(P) = -2/3$ $P =$	-6	1/4	-4	none of these	-1/4
33. Rewrite $(10^{-2}) = 0.01$ in log form. e.g. $\log_x(y) = z$	$\log_{10}(-2) = 0.01$	$\log_{-2}(0.01) = 10$	none of these	$\log_{10}(0.01) = -2$	$\log_{-2}(10) = 0.01$
34. $\log_8(2) + \log_8(16) = \log_8(a)$ $a =$	18	32	$8^2 + 8^{16}$	64	none of these
35. $2 \log_4(8) =$	none of these	3/2	$2(4^8)$	$4^{8/2}$ or 4^4	64
36. $c \log_b(d) =$	none of these	$\log_b(d^c)$	$\log_b(d+c)$	$\log_b(cd)$	$\log_b(d/c)$
37. $\log_3(3) - \log_3(12) = \log_3(v)$ $v =$	1/4	36	none of these	15	9
38. $\log_{10}(3.2) = x$ $x \doteq$	0.4949	3.3010	none of these	0.5051	1.5051

Test	1	2	3	4	5
39. $\log_{10}(x) = 9.0790 - 10$ $x \doteq$	0.832	none of these	0.809	-0.832	1.20
40. $\log_{10}(888) = x$ $x \doteq$	2.0516	9.4840	8.9445	none of these	2.9484
41. Rewrite $\log_m(n) = P$ in the exponential form. e.g. $x^2 = y$	$n^m = P$	$m^P = n$	none of these	$P^m = n$	$m^n = P$
42. $\log_{10}(0.587) \doteq$	-9.7686 + 10	none of these	9.7686 - 10	0.7686	-1.7686
43. Solve for b. $\log_b(16) = 4/3$ $b =$	12	10	8	none of these	64
44. $\log_{10}(10^{-5}) =$	0.00001	-5	none of these	$5(10^{-10})$	5
45. $\log_{10}(0.0069) = x$ $x \doteq$	none of these	0.8388	8.8388 - 10	7.4897 - 10	-2.1612
46. $\log_{10}(10^1) =$	11	(10^{10})	10	none of these	1
47. $\log_{10}(x) = 6.5922$ $x \doteq$	0.8191	none of these	$(8.19)(10^5)$	$(3.91)(10^6)$	84.56

Test A	1	2	3	4	5
48. $\log_{10}(x) = -2.7447$ $x \doteq$	0.0555	$5.55(10^{-2})$	none of these	0.018	$(8.7)(10^{-2})$
49. $\log_b(c) + \log_b(d) = \log_b(x)$ $x =$	$c^b + d^b$	b^{c+d}	cd	c + d	none of these
50. $\log_{10}(1.55) = x$ $x \doteq$	0.1903	1.1903	0.7033	none of these	-0.8097
51. $\log_{10}(10400) = x$ $x \doteq$	0.4170	none of these	5.0170	4.0170	10.6021

DIMENSIONAL ANALYSIS

Test A	1	2	3	4	5
52. $4bh + 2b^2 = a$ $(b \neq 0)$ h =	none of these	$\frac{a}{4h + 2b}$	$a-(2b^2 + 4b)$	$(a + 2b^2)/(4b)$	$\frac{a}{4b} + \frac{b}{2}$
53. $u_1 = 4u_2$, $u_2 = 9u_3$, $2.4u_1 = xu_3$ x =	none of these	$2.4(9^3/4^2)$	$2.4(4/9)$	$2.4(36)$	$2.4(9/4)$
54. $m_1 = 4m_2$, $5m_2 = m_3$ $100(m_1)^2 = x(m_3)^2$ x =	$(8.0)(10^1)$	$6.4(10^2)$	none of these	$(2.0)(10^3)$	$(1.46)(10^2)$
55. $-x + 4/(3p) = 6e$ x =	$6e - 4/(3p)$	$6e - 3/(4p)$	$3(p/4 - 2e)$	none of these	$3/(4p) - 6e$
56. $17x - 7(2x - 2g) = 7x - 6(x + 4g)$ x =	19g	-14g	14g	none of these	-10g
57. $2y(a/2 - b/4) + (4a - 2b) = 2ab$ y =	$\frac{2ab}{a-b/2} + \frac{2b-4a}{a-b/2}$	$4[ab-(2a-b)]/a-b/4$	$-4(2a-ab-b)/(a-b/2)$	$2(2a-ab-b)/(a-b/2)$	none of these
58. $2(h+b) = 3h+18b$ h =	-16b	4b	20b	none of these	16b/5

Test A	1	2	3	4	5
59. $4u_1 = 1u_2$, $6u_1 = 1u_3$ $5.4(u_2)^2 = (x)(u_3)^2$ x =	$2.4(10^0)$	$15(10^0)$	$3.6(10^1)$	$7.2(10^0)$	none of these
60. $6(3x-4r) = 2x-4r$ x =	0.00r	none of these	1.20r	$(6.25)(10^{-1})r$	-1.0r
61. $5(x+3) - (9-4x) = 2x + 18$ x =	12/7	7/2	12	2.0	none of these
62. $8bh+4b^2 = 7a$ h =	$7a-4b^2-8b$	$1/8(7a/b+4b)$	none of these	$7a/(8b) - 2b$	$(7a-4b^2)/(8b)$
63. $4y-521ml = 7ml$ y =	$(5.14)(10^2)ml$	$(1.285)(10^2)ml$	528ml	none of these	$(1.32)(10^2)ml$
64. $(-3)(3y-5m) = y - 19m$ y =	-1.4m	4.25m	-1.167m	none of these	3.4m

EXPONENTS

Test B	1	2	3	4	5
1. $(-9/5)^3 =$	none of these	$9^{-3}/5^3$	$-9/5^3$	$(-9)^{3/5}$	$(-9)^3/5^3$
2. $0.8^{1/3} =$	-0.512	0.2	1/0.512	$1/\sqrt[3]{0.8}$	none of these
3. $(2.20)(10^0) =$	none of these	1	0.220	2.20	0
4. $9^8/9^3 =$	9^{11}	9^5	none of these	$9^{8/3}$	$9^{(3-8)}$
5. $[(3)(5)]^9 =$	$(3^9)(5^9)$	none of these	$(3)^3(5)^3$	$(15)^{18}$	$(3)^6(5)^3$
6. $[(6.20)(10^{-2})]/(-3.10) =$	$(2.00)(10^{-2})$	$(2.00)(10^{-3})$	$(-2.00)(10^{-1})$	none of these	$(-2.00)(10^{-2})$
7. $[3(x)(-y)]^2 =$	$(-9xy)^2$	$-9x^2y^2$	$9(x-y)^2$	none of these	$3^2x^3(-y)^3$
8. y^3/z^5 $(z \neq 0)$	none of these	yz^8	y^3-z^5	$yz^{3/5}$	yz^{-2}
9. $(5^6)^{-3}$	5^3	none of these	5^{-9}	5^{-3}	5^{18}
10. Express $(1.5)^2$ in scientific notation.	$\log_{1.5}(2.25) = 2$	$(2.25)(10^0)$	$\log_{10}(2.25) = 0.3522$	none of these	$(2.25)(10^1)$
11. $(4)^{10} =$	none of these	$(4^{-5})^{15}$	$[(4)]^9$	$(4^5)^5$	$(4^{-5})^{-2}$

Exponents - Page 2

Test B	1	2	3	4	5
12. $[(P-(3/4))^t]^x =$	$(P-(3/4))^{t+x}$	$(P-(3/4))^{x/t}$	$(P^t-(3/4)^t)^x$	$(P-(3/4))^{tx}$	none of these
13. Express 114,000,000 in scientific notation.	$(1.14)(10^8)$	none of these	$(0.114)(10^9)$	$(114)(10^6)$	$(11.4)(10^7)$
14. $(3^5)(3^{12}) =$	9^{60}	none of these	3^{17}	$3^{12/5}$	3^{60}
15. $(ab)^6x^{3y}/(abx^{-y}) =$	$(ab)^5x^{2y}$	$(ab)^5x^{4y}$	$(abx)^{17y}$	$(abx)^{10y}$	none of these
16. $(-0.07)^{-4} =$	$(0.07)^4$	$\sqrt[4]{-0.07}$	none of these	0.28	$1/(0.0049)^2$
17. $(-0.02)(10^5) =$	-2000	none of these	0.0000002	1/2000	-0.0000002
18. $(0.05)(5^{10}) =$	none of these	500,000,000	0.000000000005	$(5.0)(5^8)$	$(5.0)(5^{12})$
19. $[(4a^2+4ab+b^2)^2]^3 =$	$(4a^2 + 4ab + b^2)^6$	none of these	$(4a^2)^5+(4ab)^5+(b^2)^5$	$(4a^2+4ab+b^2)^5$	$(2a+b)^7$
20. $8^{2/3}$	0.25	none of these	$\sqrt[2]{512}$	$1/8^{3/2}$	4
21. $(4^{3/2})(4^{1/2}) =$	$4^{3/4}$	4^2	4^3	4	none of these
22. $[(5-2)(4+2)]^4 =$	9^4	$5^4 4^4$	$(5-2)^4(4+2)^4$	none of these	$(5-2)^5(4+2)^5$
23. $7^0 =$	0	none of these	1	7	1/7

Test B	1	2	3	4	5
24. $(7/(-4))^5 =$	$7^5/(-4)$	none of these	$7/(-4)^5$	$7/4^{-5}$	$7^5/4^{-5}$
25. $(r+2s)^{-2}(r+2s)^4 =$	$(r+2s)^{-8}$	$(r)^2+(2s)^2$	$(r+2s)^{-6}$	$(r+2s)^{-2}$	none of these
26. $(-5/3)^{-5} =$	$(-5)^5/3^{-5}$	$(-5)^{-5}/(-3)^{-5}$	$3^5/(-5)^5$	none of these	$5^5/3^{-5}$
27. $(-x)^{-1} =$	$-x$	none of these	x	$-1/x$	0
28. Express (-0.00008)(0.004) in scientific notation.	$(-320)(10^9)$	$(-3.20)(10^7)$	$(-32.00)(10^6)$	none of these	$(-0.320)(10^6)$
29. $(7/9)^{-3} =$	$(-7)^3/(-9)^3$	$7^{-3}/9^{-3}$	$7^3/9^{-3}$	none of these	$1/(7^3 9^3)$
30. Express (-0.010201) in scientific notation.	$\log_{0.101}(-0.010201) = 2$	$-(0.101)^2$	none of these	$(1.00001)(10^{-1})$	$(-0.101)^2$

LOGARITHMS

Test B	1	2	3	4	5
31. $\log_4(a)-\log_4(8a) = \log_4(z)$ $z =$	$4^{(-9a)}$	$-7a$	none of these	$-8a^2$	$1/8$
32. $\log_{16}(P) = -3/4$ $P =$	$1/8$	$-1/8$	-12	-8	none of these
33. Rewrite $10^4 = 10,000$ in log form. e.g. $\log_x(y) = z$	$\log_{10}(4) = 10,000$	none of these	$\log_4(10,000) = 10$	$\log_4(10) = 10,000$	$\log_{10}(10,000) = 4$
34. $\log_{10}(5)+\log_{10}(10) = \log_{10}(x)$ $x =$	none of these	50	10^{15}	15	10^5+10^{15}
35. $2\log_3(9) =$	$3^{9/2}$	81	$2(3^9)$	2	none of these
36. $2\log_c(f) =$	$\log_c(2+f)$	$\log_c(f^2)$	$\log_c(2f)$	$\log_c(f/2)$	none of these
37. $\log_2(16)-\log_2(4) = \log_2(y)$ $y =$	2	64	4	12	none of these
38. $\log_{10}(1.32) = x$ $x \doteq$	1.1206	0.1206	0.5051	none of these	0.8794

Test B	1	2	3	4	5
39. $\log_{10}(x) = 7.7860-10$ $x \doteq$	1.64	0.0611	0.0164	0.0601	none of these
40. $\log_{10}(793) = x$ $x \doteq$	2.1007	none of these	2.8993	7.9685	(8)(9980)
41 Rewrite $\log_a(b) = c$ in the exponential form. e.g. $x^2 = y$	$a^c = b$	$b^c = a$	$a^b = c$	$c^a = b$	none of these
42. $\log_{10}(0.441) = x$ $x =$	9.6444-10	-1.6444	-9.6444+10	0.6444	none of these
43. $\log_b(27) = 3/2$ $b =$	9	18	81	10	none of these
44. $\log_{10}(10^3) =$	1000	none of these	13	3	$3(10^{10})$
45. $\log_{10}(0.0823) = x$ $x \doteq$	-1.0846	8.6653-10	-0.9154	none of these	9.9154-10
46. $\log_{10}(10^{-2}) =$	none of these	8	-2	0.01	$-2(10^{10})$

Test B	1	2	3	4	5
47. $\log_{10}(x) = 3.5391$ $x \doteq$	$(5.49)(10^2)$	0.5488	$(3.46)(10^3)$	2.26	none of these
48. $\log_{10}(x) = -1.4861$ $x \doteq$	0.0327	0.173	none of these	$(1.4)(10^{-1})$	$(1.73)(10^{-1})$
49. $\log_x(y)+\log_x(2y) = \log_x(z)$ $z =$	x^y+x^{2y}	x^{3y}	none of these	$2y^2$	3y
50. $\log_{10}(5.05) = x$ $x \doteq$	1.7033	none of these	-0.2967	0.7033	5.6990
51. $\log_{10}(50600) = x$ $x =$	5.2968	5.7042	1.1042	none of these	4.7042

DIMENSIONAL ANALYSIS

Test B		1	2	3	4	5
52. $3bh+4b^2 = 2c^2$	$h =$	$2(c+b)^2/(3b)$	$2c^2+4b^2-3b$	none of these	$2c^2/(3b)+4b/3$	$2c^2 + 4b^2/(3b)$
53. $n_1 = 6n_2$, $n_2 = 15n_3$ $2.4n_1 = xn_3$	$x =$	$9.6(10^{-1})$	$2.16(10^2)$	$2.67(10^{-1})$	none of these	6.0
54. $n_1 = 5n_2$, $3n_2 = n_3$ $45(n_1)^2 = x(n_3)^2$	$x =$	$(6.25)(10^2)$	$(7.5)(10^1)$	$(6.75)(10^2)$	none of these	$(1.25)(10^1)$
55. $-y+5/(8P) = 4g$	$y =$	$4g-5/(8P)$	$4g-5P/8$	none of these	$5/(2P)-g$	$8(P/5-g/2)$
56. $18x-6(3x-1g) = 8x-5(x+3g)$	$x =$	none of these	$-7g$	$-3g$	$3g$	$-(1/3)g$
57. $x(a^2+b^2) - (a+b) = ab$	$x =$	$(ab+a+b)/(a^2+b^2)$	none of these	$ab/(a+b)-1/(a^2+b^2)$	$[ab-(a+b)]/(a^2+b^2)$	$ab-(a^2+b^2)+a+b$
58. $4(h+b) = h+22b$	$h =$	$23/(5b)$	3	$7b$	$6b$	none of these

Dimensional Analysis - Page 2

Test B		1	2	3	4	5
59. $3n_1 = 1n_2$. $4n_1 = 1n_3$ $(n_2)^2 = (x)^2 n_3{}^2$	$x =$	$(8.0)(10^2)$	$(7.2)(10^2)$	$(3.2)(10^3)$	none of these	$(1.54)(10)^3$
60. $7(2x+3g) = 4x - 3g$	$x =$	$(3.5)(10^{-1})g$	$-0.35g$	$(2.47)(10^2)g$	$-2.4g$	none of these
61. $5(2x+3)-(10-3x) = 7x-9$	$x =$	$-4/3$	$-2/3$	$-13/6$	$-8/3$	none of these
62. $4bh+2b^2 = a$ $(b \neq 0)$	$h =$	none of these	$1/2(a/2b+b)$	$(a-2b^2)/(4b)$	$2(a/2b-b)$	$a-2b^2-4b$
63. $3y-432mm = 6mm$	$y =$	146m	none of these	$(1.46)(10^2)$mm	438mm	$(4.26)(10^2)$mm
64. $(-2)(4y-3m) = 2y-15m$	$y =$	2.1m	none of these	-10.5m	3.5m	0.9m

APPENDIX C

SCORING KEY TO PRETEST/POSTTEST

APPENDIX C

Math Skills Pretest/Posttest Scoring Key

Form A

Exponents

Subtest	Item	Answer
1 *Definition of Exponents*	2	5
	3	3
	16	5
	17	3
	18	5
	20	2
	23	2
	27	1
2 *Definition of Scientific Notation*	10	1
	13	2
	28	4
	30	3
3 *Laws of Exponents and Their Application*	1	1
	4	2
	5	4
	6	2
	7	2
	8	2
	9	2
	11	1
	12	4
	14	5
	15	1
	19	5
	21	5
	22	1
	24	2
	25	1
	26	4
	29	2
	30	
	**p=26*	

Logs

Subtest	Item	Answer
4 *Definition of Logarithms*	32	2
	33	4
	41	2
	43	3
5 *Properties of Logarithms and Their Application*	31	4
	34	2
	35	1
	36	2
	37	1
	49	3
6 *Common Logs from a Table of Mantissas*	38	4
	40	5
	42	3
	44	2
	45	5
	46	5
	50	1
	51	4
7 *Antilogs from a Table of Mantissas*	39	2
	47	4
	48	3
		21
		**p=18*

Dimensional Analysis

Subtest	Item	Answer
8 *Unit Conversions*	53	4
	54	3
	59	1
9 *Solutions of Linear Equations*	52	1
	55	4
	56	4
	57	1
	58	1
	60	2
	61	1
	62	5
	63	5
	64	5
		13
		**p=11*

**p indicates the least score for which instruction is not recommended.*

Math Skills Pretest/Posttest Scoring Key

Form B

Exponents

Subtest	Item	Answer
1 *Definition of Exponents*	2	5
	3	4
	16	5
	17	1
	18	1
	20	5
	23	3
	27	4
2 *Definition of Scientific Notation*	10	2
	13	1
	28	4
	30	3
3 *Laws of Exponents and Their Application*	1	5
	4	2
	5	1
	6	5
	7	4
	8	1
	9	2
	11	5
	12	4
	14	3
	15	2
	19	1
	21	2
	22	3
	24	2
	25	5
	26	3
	29	2

30
**p=26*

Logarithms

Subtest	Item	Answer
4 *Definition of Logarithms*	32	1
	33	5
	41	1
	43	1
5 *Properties of Logarithms and Their Application*	31	5
	34	2
	35	5
	36	2
	37	3
	49	4
6 *Common Logs from a Table of Mantissas*	38	2
	40	3
	42	1
	44	4
	45	1
	46	3
	50	4
	51	5
7 *Antilogs from a Table of Mantissas*	39	5
	47	3
	48	1

21
**p=18*

Dimensional Analysis

Subtest	Item	Answer
8 *Unit Conversions*	53	2
	54	4
	59	4
9 *Solutions of Linear Equations*	52	3
	55	3
	56	1
	57	2
	58	4
	60	4
	61	5
	62	3
	63	3
	64	1

13
**p=11*

**p indicates the least score for which instruction is not recommended.*

APPENDIX D

ATTITUDE INVENTORY

APPENDIX D: ATTITUDE INVENTORY

NAME: ______________________________ DATE ______________
Last First Middle Initial

Your answers to the following questions concerning the Computer-Assisted Instruction (CAI) Math Skills program will help us to improve the program. Please circle the letter corresponding to your answer.

---

1. Do you feel that the CAI program helped you to lose some of your hang-ups with regard to the equations and concepts used in your coursework?

   a. It helped a great deal.

   b. It helped some.

   c. It didn't help.

   d. It gave me more hang-ups.

2. A CAI program communicates with the student by means of either a typewriter or a typewriter keyboard and a TV-like screen. How do you like the kind of terminal you used?

   a. I like it very much.

   b. It is okay.

   c. I don't really care for it.

   d. I felt like the prisoner of a mechanical monster.

3. When the program presented concepts and rules for you to learn, were they clearly presented and understandable?

   a. In general, all the material was easily understood.

   b. Most of the material was easily understood, but some was not.

   c. Most of the material was difficult to understand.

   d. In general, all the material was difficult to understand.

4. Were the questions asked you by the program clearly stated so that you knew what kind of an answer was expected?

   a. They were almost always clearly stated.

   b. Most were clearly stated.

   c. Most were poorly stated.

   d. They were almost always poorly stated.

5. CAI requires that you restrict your answers to one of a number of forms that the program can understand. Did you have difficulty in making the program accept your answers when they were really correct?

   a. I seldom had any problems with the form in which I entered my questions.

   b. I had some problems but the program didn't seem to be too restrictive.

   c. I had some problems and the program did seem to be too restrictive.

   d. The program was so pickey that it gave me a lot of trouble.

6. It is always a problem to decide how quickly new material should be presented to the student. If the instruction is too slow and gradual, it becomes boring but if the instruction jumps too quickly from one concept to another, the student is liable to get lost. Do you think that this program moved too slowly or too quickly?

   a. Much too slowly.

   b. A little too slowly.

   c. Just about right.

   d. A little too quickly.

   e. Much too quickly.

7. As a means of evaluating this program, we have given different students different amounts of control over the way in which they could learn the material. As a student is given more control, however, this means that the course material is also less structured; that is, the student has to make more decisions about whether or not he really knows some topic and is ready to learn some other topic. Would you like to have more or less control over how the material was presented to you?

   a. The program was much too rigid and I could have made better decisions on my own.

   b. I would like to make a few more decisions on my own.

   c. It seemed about right.

   d. I had to make a few too many decisions.

   e. I was so busy making decisions about what to do next that it slowed down my learning.

8. As compared to other ways of learning this material, I think CAI is:

a. Better than having an individual tutor.

b. About as good as having an individual tutor.

c. About as good as classroom instruction.

d. About as good as learning the material from a book.

e. Worse than learning the material from a book.

9. For the rest of the time that you will be in college, how much of your instruction would you like to be by CAI?

a. I would like to take most of my courses by CAI.

b. I would like to take a few of my courses by CAI.

c. I wouldn't mind one or two courses by CAI.

d. I never want to use CAI again.

10. Was CAI either not available or not working when you arrived for your appointment?

a. It was always working and available.

It was broken or not available:

b. Once.

c. Twice.

d. More than twice.

11. About how much time have you spent on this CAI Math course?

a. Two hours or less.

b. Two to four hours.

c. Four to six hours.

d. Six to nine hours.

e. Nine to twelve hours.

f. Twelve to fifteen hours.

g. More than fifteen hours.

12. If you had been the author of this program, how would you have changed it to make it easier for the student?